https://doi.org/10.26682/sjuod.2023.26.1.24
Journal of University of Duhok., Vol. 26, No.1 (Pure and Engineering Sciences),Pp 236-243, 2023

RETREATABILITY OF BIOCERAMIC SEALERS UESD WITH SINGLE CONE OBTURATION: SEM ASSESSMENT

NISHTIMAN **S**HINO **K**HALID and **A**DULLKAREEM **R**AMAZAN **A**L-**M**EZORY
Dept. of prosthodontics, College of Dentistry, University of, Kurdistan Region-Iraq

(Received: January 8, 2023; Accepted for Publication: April 13, 2023)

ABSTRACT

Aim: The aim of this study is to evaluate the retreatability of bioceramic sealers (Endosequence BC, Totalfill BC, MTA-Fillapex) used with single cone obturation technique.

Materials and methods: Root canal of forty single rooted human mandibular premolar teeth were prepared with ProTaper Next rotary system up to X3 and obturated with single cone technique (n=10) using endosequence BC (A), Totallfill BC (B), MTA-Fillapex (C) and Zinc oxide (D) sealer, after two weeks, all samples retreated with ProTaper Universal Retreatment rotary files. regaining of working length and apical patency was evaluated. All samples longitudinally sectioned and assessed by Scanning electron microscope to evaluate the residual filling materials and the data statistically analyzed.

Results: The least amount of residual filling materials was found in group D-ZOE (1.43) followed by group C-MTA-Fillapex (1.50) and B-Totalfill BC (1.57) respectively. While, the greater amount was in group A-Endosequence BC (1.87). Furthermore, the working length was re-gained 100% of all samples. Whereas, the patency regained in group A, B, C and D was 90%, 80%, 90%,100% respectively.

Conclusion: None of the root canal filling materials could be completely removed. The greater amount of residual filling materials was observed in bioceramic sealers than the ZOE sealer. Furthermore, the working length regained 100% of samples. While, there was loss of patency in some cases.

***KEYWORDS*:** Bioceramic Sealers, Endosequence BC Sealer, Residual Filling Materials, Retreatment.

INTRODUCTION

The ultimate goal of root canal treatment is the prevention or healing of apical lesion. The use of biologically active materials to seal root canal systems has been extensively proposed in contemporary endodontics to realize this goal. (Teja and Ramesh 2020). Till now, the most accepted and widely used root canal filling materials for obturation the root canal system are the gutta perchea with different types of sealers. As the gutta perchea alone failed to provide effective hermetic seal, the sealers are applied to fill the voids and irregularities between root filling materials and canal walls and lateral or accessory canals. (Al-Dahman and Al-Omeri 2021). The most recent developed sealer is the bioceramic sealers, which is their biocompatibility, high alkalinity, providing compact sealing and non-soluble after setting making their uses more prominent over time. Thus these sealers considered one of the most effective sealer in conjunction with core filling material for obturation of root canal space and the manufacturer recommended for using with single cone obturation technique. (Zhekov et al.,2020).

While, the endodontic treatment not always successful and failure could occur in some percentages of cases due to several reasons. (Oltra et al.,2016). Once, the primary endodontic treatment is not successful, the most conservative option is the retreatment procedure. The remaining root canal filling materials decrease the chance of success of retreatment procedure since, it is lead to mechanical barrier that cause insufficient irrigation and disinfection of contaminated root canal and the periapical lesion persist. For that, the effective removal of previous filling materials is considered the essential part of non-surgical retreatment procedure. (Athkuri et al.,2019). The attractive advantages associated with bioceramic sealers makes these sealers more and more popular. their retreatability during endodontic failure among clinicians is concerning. Thus, this study conducted to evaluate the retreatability of these sealers used in single cone obturation technique.

MATERIALS AND METHOD

Sample preparation

Forty single rooted human lower premolars extracted for orthodontic purpose were used. Teeth were verified with mesiodistal and

buccolingual radiographs as having single canal. Teeth with previous root filling, calcification, immature apices and resorptive defects were discarded. The external surfaces of all samples were cleaned using ultrasonic scaler to remove any calculus and soft tissue then, disinfected with 5.25% sodium hypochlorite (NaOCl) solution for 10 min and stored in normal saline until use. All teeth samples were decoronated using diamond disc and formed standardized sample with (12 mm) length. After that, a stainless steel #10 K-file were inserted in the canal until it was visible at the apical foramen and the working length (WL) was determined by subtracting 1 mm from that measurement. To facilitate the handling of root samples during instrumentation and obturation, the putty of condensational polysiloxane impression material was mixed with the catalyst gel according to the manufacture's instruction and inserted in to the custom made metal ring (30mm height and 10mm width). each root samples were individually placed in the center of it and waited until complete setting occurred then the instrumentation started.

The root canal intrumentation was carried out using ProTaper Next Rotary System (Dentsply Maillefer, Ballaigues, Switzerland) (PTN) up to size X3 (size 30, taper .07) with speed 300 rpm and torque of 2.8 N/cm. Between each instrument change, the canals were irrigated with 2ml of 5.25% NaOCl and each file was discarded after preparing five samples. The final irrigation was performed with 2ml of 5.25% NaOCl solution, and the 17% EDTA was applied for 1 minute to remove the smear layer. All the irrigants were activated by using activation device (Ultra X Ultrasonic activator-Eighteeth) for 20s. Subsequently, the canals were flushed with normal saline and dried by using absorbing paper point size X3. The prepared canals were randomly divided in to four groups (n=10) according to the sealer used as follow: A-Endosequence BC, B-Totallfill BC, C-MTA-Fillapex, D-Zinc oxide. All samples obturated with single cone technique(SC). and the type of sealer placed in canal according to manufacturer's instruction. The quality of obturation of all samples were assessed by using the buccolingual and mesiodistal radiographs. Then the root orifices were sealed with temporary filling and stored at 37°C in 100% humidity for two weeks.

Table (1): Composition of sealers used in this study.

Sealer	Manufacturer	Sealer contents
Endosequence BC sealer	Brasseler USA, Savannah, GA, USA	(injectable form) a premixed syringe of Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler, and thickening agent.
Total Fill BC sealer	FKG Dentaire, La-Chaux-de-Fonds, Switzerland	premixed single syringe which contains Zirconium oxide, dicalcium silicate, tricalcium silicate, calcium hydroxide and fillers.
MTA Fillapex sealer	Angelus, Londrina, PR, Brazil	natural resin, salicylate resin, diluting resin, bismuth trioxide, nanoparticulated silica, pigments and MTA (40%, tricalcium silicate, dicalcium silicate, calcium oxide, tricalcium aluminate),
Zinc oxide eugenol sealer-EndoFill	(Endofill; Produits Dentaires SA, Vevey, Switzerland).	Powder: Zinc oxide, staybelite resin, bismuth subcarbonate, barium sulfate, sodium borate anhydrate. Liquid: eugenol.

Retreatment of root canal filling:

The ProTaper Universal Retreatment (PTR) system D1, D2, and D3 rotary files were used for removal of obturating materials from the coronal, middle, and apical thirds, respectively with speed 500 rpm and torque 2.0 N/cm following the manufacturer's instructions, each file was discarded after using in five samples. No solvents were used to soften the gutta perchea and each file was discarded after preparing five canals. Furthermore, the aforementioned irrigation protocol was applied during the retreatment procedure. The retreatment procedure was considered completed when no evident of the obturating material could be seen on the last file D3 (Yung, et al.,2021). The ability to reach the WL and regain patency was checked by using small stainless steel K-files (#10). Apical Patency was confirmed by visualization of the file in to apical foramen (Paiva et al.,2018).

After the retreatment procedure all samples were vertically grooved baccully and lingually along the long axis of the root without

penetrating the canal space using a diamond disc. then splitted longitudinally with chisel in to two halves. scanning electron microscope (SEM) photomicrograph was taken at the center of each root canal third (Coronal, Middle, Apical) at magnifications (×1000) (Kakoura and Pantelidou 2018). scoring system was used to assess the quantity of the residual root canal filling materials as follow: score 1: 0-25% no or slight presence of residual filling materials on dentin surface, score 2: 25-50% presence of some residual filling materials, score 3: 50-75% presence of moderate amounts of residual filling materials, score 4: 75-100% heavy presence of residual filling materials (Al-Dahman and Al-Omeri.,2021).

RESULTS

Residual root canal filling materials in the total canal area of all study groups.

The data in table (2) and figure (1) presented the mean values of score of residual root canal filling materials in total canal area of all study groups. the statistical analysis demonstrated that there was no significant difference in the score of residual root canal filling materials in the total canal area between all study groups($p<0.01$).

Table (2): Comparisons of the score of residual root canal filling materials in the total canal area of all study groups:

Study group (n=10 each)	Residual filling materials		
	Mean	Std Dev	P (two-sided)
	1.87	0.42	0.1022
A-Endosequence BC sealer	1.57	0.35	
B-Totallfill BC sealer	1.50	0.28	
C-MTA-Fillapex sealer	1.43	0.42	
D-ZOE sealer			
Kruskal Wallis test was performed for statistical analyses.			

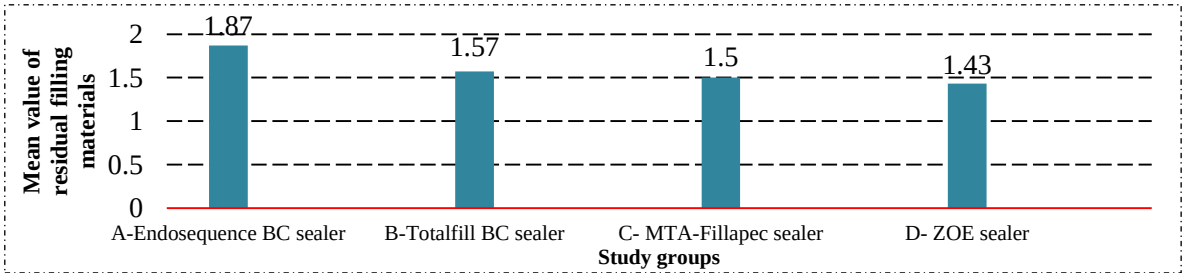

Fig. (1): Bar graph showing the means of score of the residual root canal filling materials after retreatment procedure.

Residual root canal filling materials of canal thirds (coronal, middle, apical) of each study groups.

The data in table (3) and figure (2) presented the mean values of score of residual root canal filling materials in coronal, middle and apical third of each study groups. Statistical analysis demonstrated that there was no significant difference.

Table (3): Comparisons of score of the residual root canal filling materials in canal thirds within study groups

Study groups (n=10 each)	Residual filling materials			Pairwise comparisons
	Mean	Std Dev	P (two-sided)	
A-Endosequence BC sealer			0.1728	
Coronal	1.8	0.79		
Middle	1.5	0.71		
Apical	2.3	1.06		
B-Totalfill BC sealer			0.8170	
Coronal	1.4	0.52		
Middle	1.5	0.53		
Apical	1.6	0.70		

C-MTA-Fillapex sealer			0.0668
Coronal	1.6	0.70	
Middle	1.2	0.42	
Apical	1.9	0.74	
D-ZOE sealer			0.5376
Coronal	1.5	0.85	
Middle	1.2	0.42	
Apical	1.6	0.84	
Kruskal Wallis test was performed for statistical analyses.			

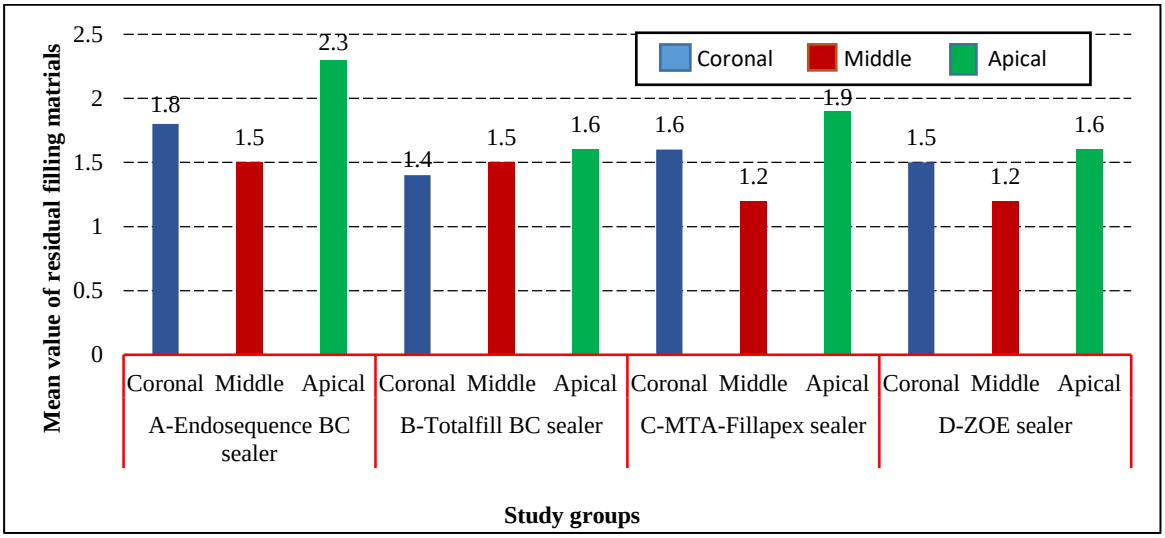

Fig. (2): Bar graph showing the filling materials remaining in canal thirds after retreatment of each study groups.

The percentage of the ability to reach working length and patency during retreatment:

The data in table (4) and figure (3) showed that the working length was re-established in 100% in all samples of all study groups. whereas, the percentage for regain patency during retreatment was 90%, 80% and 90% ,100% for group A, B, C and D respectively. there was no significant difference in regained patency between study groups ($p < 0.01$).

Table (4): Comparisons of percentage of ability to reach working length and patency during retreatment between study groups

Study groups(n=10 each)	**Outcome no (%)**		
	Working length	**Patency**	**P (two-sided)**
A- Endosequence BC Sealer-SC	10(100)	9 (90.0)	0.2969
B- MTA-Fillapex Sealer-SC	10 (100)	8 (80.0)	
C- TotalFill BC sealer-SC	10(100)	9 (90.0)	
D- ZOE Sealer-SC	10(100)	10 (100)	

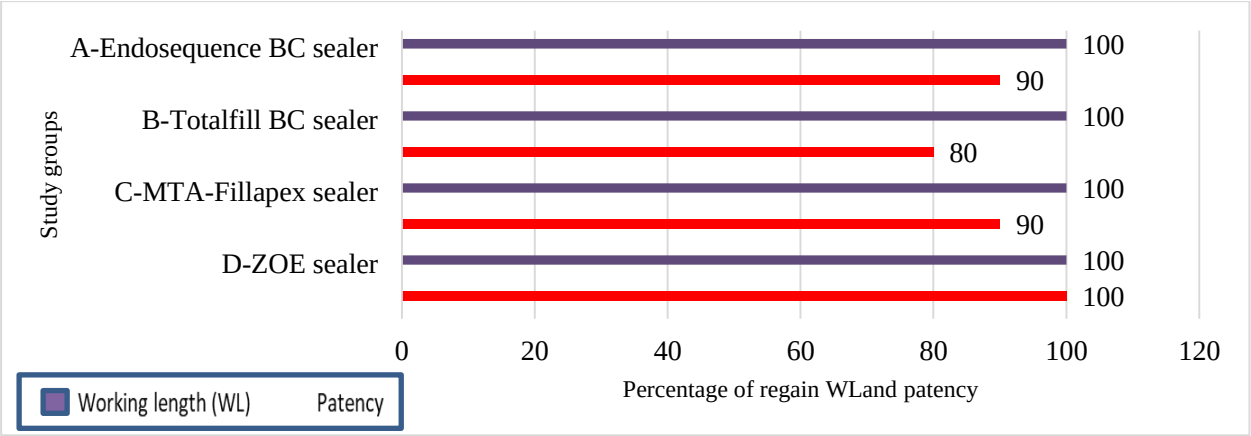

Fig. (3): The percentage of regaining WL and patency during retreatment of each study groups

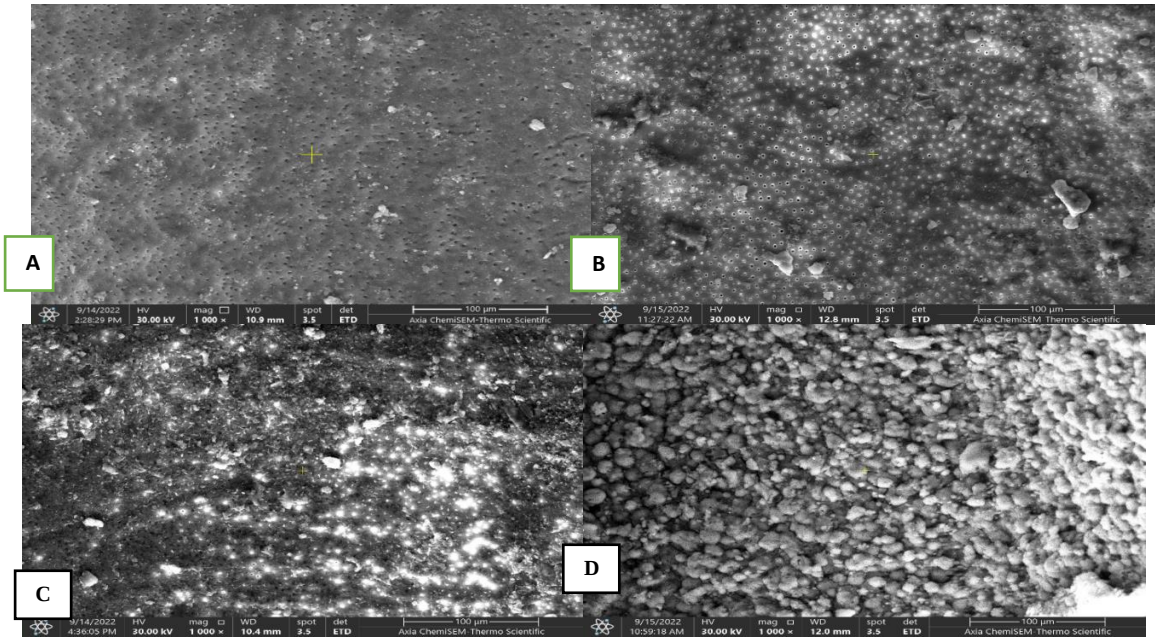

Fig. (4): SEM image at magnification1000x.(A)score 1 (B)score 2 (c)score 3 (D)score 4.

DISCUSSION

In this study the MTA-Fillapex sealer used as the first commercially available calcium silicate-based sealer. which is composed of 40% of MTA and salicylate resin. Many studies showed that this sealer has deeper and greater penetration into dentinal tubules when compared with another sealer (Antunovic et al.,2021). Additionally, endosequence BC and Totalfill BC sealer used as the newest generation of calcium silicate-based sealer that has been induces the formation of hydroxyapatite tags which is increases the push-out bond strength of those sealer. this bond could make removal very difficult if retreatment is necessary. (Salim et al.,2021; Mufti et al.,2021). Furthermore, those three types of sealer in this study compared with zinc oxide eugenol sealer because this sealer considered one of the oldest and most popular used sealer in endodontic treatment, known for their acceptable sealing ability and adequate tissue tolerance (obeid and Nagy,2016). By the development of proTaper Next rotary system maintain the obturation technique easier and faster as the prepared canal obtuarted with matched single cone gutta-percha (Pereira et al.,2012). As well, with the introduction of bioceramic sealers induced new interest for using this obturation technique. (Pontorioro et al.,2021). The retreatment procedure was carried out by using ProTaper universal retreatment system(PTUR) as known for it is efficacy of removal of root canal filling materials (Mufti and Al-Nazhan.,2021).

This study showed that there was no significant difference of residual root canal filling materials in the total canal area between all study groups. The greater amount of residual

filling materials found in group obturated with Endosequence BC and Totalfill BC sealer as showed in table (2). This results could be imputed to the fact that the endsequence BC sealer and Totafill BC sealer has potential to adhere to the dentin (Trope et al.,2015; Xavier et al.,2019) and provide higher bonding strength than other type of sealers as the result of the formation of tag-like structure by intratubular precipitation of calcium and phosphate materials (Shukri and Hadi.,2021). these results are in agreement with the study of Zuolo et al.,2016 who evaluated the removal ability of the BCS compared with a zinc oxide eugenol–based sealer. The groups that were filled with BCS exhibited a higher percentage of residual filling material than the zinc oxide group. As well are correlated with the Kakoura and pantelidou 2018 study who used the SEM to observe the residual filling materials of AH26 sealer, Totalfill BC sealer and BioRoot RCS sealer they reported that the Totalfill BC sealer left more filling materials than other types of sealers. While, disagreed with the result reported by Ersve et at.,2012 who observed no differences in the amounts of remaining filling material after the retreatment of palatal roots filled with Hybrid Root SEAL, Endosequence bioceramic BCS sealer and AH plus.

MTA-Fillapex sealer left less residual filling materials than the endosequence and Totallfill BC sealer as showed in table (2). This finding could be attributed to the low adhesion capacity of MTA-Fillapex sealer to the root dentin as the Nagas et al.,2014; Reyhani et al.,2014 concluded that the MTA-Fillapex has lower bonding strength when compared with another sealer. Additionally, it could be as the result of the low content of MTA in fillapex sealer which is quite not enough for inducing biomineralization. as this biomineralization process is claimed to enhance the resistance of dislodgement of MTA from dentin (Reyes et al.,2010). this finding coincide with the result stated by Donyavi et al.,2019 study who showed that the MTA Fillapex exhibited less residual filling materials. Whereas, the least amount of residual filling materials in this study was observed in ZOE group. this finding is corroborating with the result of Obeid et al.,2016 study where they used stereomicroscope to evaluate the retreatability of MTA-Fillapex, AH plus and zinc oxide eugenol sealer found that the ZOE was the easier one for removal. While, this result is contrary to the result reported by Santos et al.,2017 who showed that MTA-Fillapex Root canals presented least amount of residual filling materials when compared with the Zinc oxide eugenol sealer, Sealapex sealer, AH Plus and Resilon/Real Seal.

Comparison of the apical, middle, and coronal one-thirds of the canals regardless of the type of sealers used, in the present study the greater amount of residual filling materials was observed in the apical third than the coronal and middle third respectively as showed in table (3). This finding may be related to the difference of progressive taper of PTUR system which led to the better cutting in the coronal third as the result of continuous rotation of the rotary file during retreatment in the region with high concentration of filling materials (Bramante et al.,2010). another reason is the difference between tip sizes and the taperness of canal preparation file which was X3 and retreatment file D3 (Khalilak et al.,2013). As, the apical third considered a critical zone which has greater anatomical variations Therefore, these anatomical variations could make the removal of the filling material more difficult in this region (Simsek et al.,2014). These results in agreement with results reported by Sharif et al.,2017 study who stated that the greater amount of residual filling materials remained in apical third than that the middle and coronal thirds after retreatment of root canals. In contrast to the results of this study, some previous studies (Uzunoglu et al.,2015; Mufti et al.,2021) they showed that the greater amount of residual filling materials in the coronal third of the canal than the apical and middle thirds.

One of the major cause of endodontic treatment failure is the persistence infection, for that regaining working length and patency in retreatment cases is essential for successful outcome. this should be taken in consideration during retreatment since it might affect the periapical healing (Oltra et al.,2016; Yung et al.,2021). In this study the working length was regained in 100% of all study groups regardless of the sealers used. Whereas, the percentage of regaining patency was 90%, 80%, 90%,100% for group A, B, C and D respectively. The result about regaining WL and patency in this study coincided with some previous studies that reported the WL was regained in 100% of all groups while patency not attainment in all groups.in the study of Oltra et al.,2016 patency regained only in 14% of the boiceramic sealers samples and also Carrillo et al.,2022 reported that the percentage of regaining patency was 63% in endosequence BC group. This could be

imputed to the known fact that the calcium silicate-based sealers become very hard after complete setting, as the Hess et al.,2011 reported that the SEM analysis observed the remained bioceramic sealers in the apical foramen and prevented the regaining of patency. However, this result dissimilar to some previous studies (Agrofioti et al.,2015; Yung et al.,2021, Al-Dahman and Al-Omeri 2021) that all researchers demonstrated that the patency was regained in 100% of samples regardless of the type of sealers used. This dissimilarity could be attributed to the differences in root canal anatomy, they used anterior teeth that occasionally have wide and straight canal.

CONCLUSION

None of the root canal filling materials could be completely removed. The greater amount of residual filling materials was observed in bioceramic sealers than that the ZOE sealer. Furthermore, the working length regained 100% of samples. While, there was loss of patency in some cases.

REFERENCES

Agrafioti, A. Koursoumis, AD. Kontakiotis, EG. (2015). Re-establishing apical patency after obturation with Gutta-percha and two novel calcium silicate-based sealers. Eur J Dent.; 9:457-461.

Al- Dahman, Y., and Al- Omari, M. (2021). Retreatability of bioceramic and GuutaFlow bioseal root canal sealers using ProTaper universal system retreatment files: An Ex vivo study. Saudi Endod J.; 11:42-48.

Antunovic, M. Vukmanovic L., Budimir, A, Kabil E, Anic I, Bago I. (2021). Evaluation of sealing ability of four bioceramic root canal sealers and an epoxy resin-based sealer: An *in vitro* study. Saudi Endod J.; 11:66-72

Athkuri, S., Mandava, J., Chalasani, U., Ravi, RC., Munagapati, VK., Chennareddy, AR. (2019). Effect of different obturating techniques and sealers on the removal of filling materials during endodontic retreatment. J Conserv Dent.;22:578-82

Bramante, CM., Fidelis, NS., Assumpção, TS. (2010). Heat release, time required, and cleaning ability of MTwo R and ProTaper universal retreatment systems in the removal of filling material. J Endod 2010;36(11):1870–1873. DOI: 10.1016/j.joen.2010.08.013.

Carrillo, CA., Kirkpatrick, T., Freeman, K., Makins, SR., Aldabbagh, M., Jeong, JW. (2022). Retrievability of Calcium Silicate-based Root Canal Sealers During Retreatment: An Ex Vivo Study. J Endod.;48(6):781-786.

De Siqueira Zuolo, A., Zuolo, ML., da Silveira Bueno, CE., Chu, R., Cunha, RS. (2016). Evaluation of the Efficacy of TRUShape and Reciproc File Systems in the Removal of Root Filling Material: An Ex Vivo Micro-Computed Tomographic Study. J Endod.;42(2):315-9.

Donyavi, Z., Shokri, A., Pakseresht, Z., Tapak, L., Falahi, A., Abbaspourrokni, H. (2019). Comparative Evaluation of Retreatability of Endodontically Treated Teeth using AH 26, Fluoride Varnish and Mineral Trioxide Aggregate-based Endodontic Sealers. The Open Dentistry Journal.; (13) 183-189.

Ersev, H., Yilmaz, B., Dinçol, ME., Dağlaroğlu, R. (2012). The efficacy of ProTaper Universal rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. Int Endod J.;45(8):756-62.

Forough Reyhani, M., Ghasemi, N., Rahimi, S., Salem Milani, A., Mokhtari, H., Shakouie, S., Safarvand, H. (2014). Push-Out Bond Strength of Dorifill, Epiphany and MTA-Fillapex Sealers to Root Canal Dentin with and without Smear Layer. Iran Endod J.;9(4):246-50

Hess, D., Solomon, E., Spears, R., He, J. (2011) Retreatability of a bioceramic root canal sealing material. J Endod 37(11):1547– 1549

Kakoura F, Pantelidou O. (2018). Retreatment Efficacy of Endodontic Bioceramic Sealers: A Review of the Literature. Odovtos International Journal of Dental Sciences.;20(2):39-50.

Khalilak, Z., Vatanpour, M., Dadresanfar, B., Moshkelgosha, P., Nourbakhsh, HR. (2013). In vitro comparison of gutta-percha removal with H-File and ProTaper with or without chloroform. Iran Endod J.; 8:6–9

Kim, SR., Kwak, SW., Lee, JK., Goo, HJ., Ha, JH., Kim, HC. (2019). Efficacy and retrievability of root canal filling using calcium silicate-based and epoxy resin-based root canal sealers with matched obturation techniques. Aust Endod J. ;45(3):337-345.

Mufti, DG., Al-Nazhan, SA. (2021). Retreatability of Bioceramic Sealer Using One Curve Rotary File Assessed by Microcomputed Tomography. J Contemp Dent Pract ;22(10): 1175–1183

Nagas, E., Cehreli, Z., Uyanik, MO., Durmaz, V. (2014). Bond strength of a calcium silicate-based sealer tested in bulk or with different main core materials. Braz Oral Res.;28(1)

Obeid, MF., Nagy, MM. (2016). Retreatability of different endodontic sealers using chemical solvents, Tanta Dental Journal.;12(4): 286-291

Oltra, E., Cox, TC., Lacourse, MR., Johnson, JD. Paranjpe, A. (2016). Retreatability of two endodontic sealers, EndoSequence BC Sealer and AH Plus: a microcomputed tomographic comparison.; Restor Dent Endod.19-25.

Pereira, AC., Nishiyama, CK., Pinto, LD. (2012). Single-cone obturation technique: a literature review. RSBO.;9(4):442-447.

Pontoriero, DIK., Madaro, G., Vanagolli, V., Benedicenti, S., Verniani, G., Ferrari Cagidiaco, E., Grandini, S., Ferrari, M. (2021) Sealing ability of a bioceramic sealer used in combination with cold and warm obturation techniques. J Osseointegr ;13(4):248-255.

Reyes-Carmona, JF., Felippe, MCS., Felippe, WT. (2010). The biomineralization ability of mineral trioxide aggregate and Portland cement on dentin enhances the push-out strength. J Endod.;36:286–91.

Salim, Marina de Almeida; Ormiga, Fabiola; Lopes, Ricardo Tadeu; Gusman, Heloisa. Retreatment of mesial roots of mandibular molars filled with resin-based and bioceramic sealers.Braz. j. oral sci; 20: e210432

Santos, LG., Felippe, WT., Souzai, BD., Konrath, AC., Cordeiro, MM. (2017). Radiographic and scanning electron microscopic assessment of root canal filling remnants after endodontic re-instrumentation. Braz. Dent. Sci.; 20:80-91

Sherif, DA., Farag, AM., Darrag, AM., Shaheen, NA. (2017). Evaluation of root canals filled with bioceramic sealer after retreatment with two different techniques. Tanta Dental Journal.; 14:76–82.

Shukri, B., Hadi, MA. (2021). Comparative Assessment of the Bonding Strength of Four Types of Endodontic Sealers Using Push-Out Test. Turkish Journal of Physiotherapy and Rehabilitation ;32(1) :(3).

Simsek, N., Keles, A., Ahmetoglu, F., Ocak, MS., Yologlu, S. (2014) Comparison of different retreatment techniques and root canal sealers: a scanning electron microscope study. Braz Oral Res.; 28:1–7

Teja, KV., and Ramesh, S. (2020). An update on bioceramic sealers. Drug Invent. Today; 14 (3):17-19.

Trierveiler Paiva, RC., Solda, C., Vendramini, F., Vanni, JR., Baldissarelli Marcon, F., João Fornari, V., Martins Hartmann, MS. (2018). Regaining Apical Patency with Manual and Reciprocating Instrumentation during Retreatment. Iran Endod J. ;13(3):351-355.

Uzunoglu, E., Yilmaz, Z., Sungur, DD., Altundasar, E. (2015). Retreatability of Root Canals Obturated Using Gutta-Percha with Bioceramic, MTA and Resin-Based Sealers. Iran Endod J.;10(2): 93-8

Yang, R., Tian, J., Huang, X., Lei, S., Cai, Y., Xu, Z., Wei, X. (2021) A comparative study of dentinal tubule penetration and the retreatability of EndoSequence BC Sealer HiFlow, iRoot SP, and AH Plus with different obturation techniques. Clin Oral Investig.;25(6):4163-4173.

Zhekov, KI., Stefanova, VP. (2020). Retreatability of bioceramic endodontic sealers: a review. Folia Med (Plovdiv).;62(2):258-64.